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High-Energy Electronic X-Ray (HENEX) Spectrometer

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LLE VTC review on 28 April 2003.

Principal Investigator: John Seely, NRL

Co-Investigators:

Dr. Larry Hudson, NIST (Crystal Spectrometers)

Dr. Albert Henins, NIST (Cad designs, crystal work)

Ms. Csilla Szabo, NIST (Calibrations)

Mr. Glenn Holland, NRL (Mechanical, Detectors)

Mr. Layne Marlin, NRL (Cad Design)

Mr. Rob Atkin, TI (Control Electronics)

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HENEX deployment plan

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- HENEX is a NIF core diagnostic that will be fielded at LLE for tests.
- LLNL shots leaders during June 10-13 have agreed that HENEX can occupy TIM6 except for June 11 1400-2400 hours (occupy TIM1).
- NRL/NIST will install HENEX in TIM6 the previous week of June 2 (LLE maintenance week) for pre-shot testing.
- NRL/NIST personnel will be present the entire time and will operate HENEX.
- After this one-time deployment at LLE, HENEX will be returned to NRL/NIST for energy scale calibrations.
- HENEX will interface with the LLE DAS using the software that was developed during HXS deployment on LLE two years ago.
- HENEX can use LLE fiber optic bundles to TIM6 and TIM1?

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LLNL shots during June 10-13

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<u>The shot leaders have agreed that HENEX can ride along.</u>

- **Tuesday June 10**
  - **Andy MacKinnon**
  - **Thomson scattering**
- **Wednesday June 11**
  - **Marilyn Schneider and Bob Heeter**
  - **Hot hohlraums**
- **Thursday June 12**
  - **Frederic Girard, Michel Naudy, and Mike Miller**
  - **CEA Cu and Ti foils**
- **Friday June 13**
  - **Carmen Constantin (Mike Miller and Tina Back)**
  - **Gasbags and hohlraums with Kr and Ar.**

Action items from the 7 November 2002 review

1.LLE emails TIM CAD drawings to Layne and Glenn so the clearances at the rear of the TIM can be checked.
2.NRL provides lifting fixtures at the HENEX CG without and with the battery pack. Layne designs the lifting fixtures and sends to Greg for approval.
3.Rob sends to Greg the footprint/volume of the external electronics.
4.LLE sends to Rob the LLE computer certification guidelines.
5.Jack sends to Glenn the in-vacuum cable information and provides the cables and feedthroughs.
6.NRL provides a positive restrain to stabilize the pointer during rapid pump-down.
7.Jack and Glenn schedule the final deployment design review prior to March 2003 (a Monday at 1:00 PM is preferred).
8.The following issues were discussed. I believe it was decided that these are not required for the one-time HENEX deployment: Complete integration of HENEX into the LLE DAS, remote on/off switch, remote battery capacity sensor, automated battery charging.

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3D View of the HENEX Diagnostic

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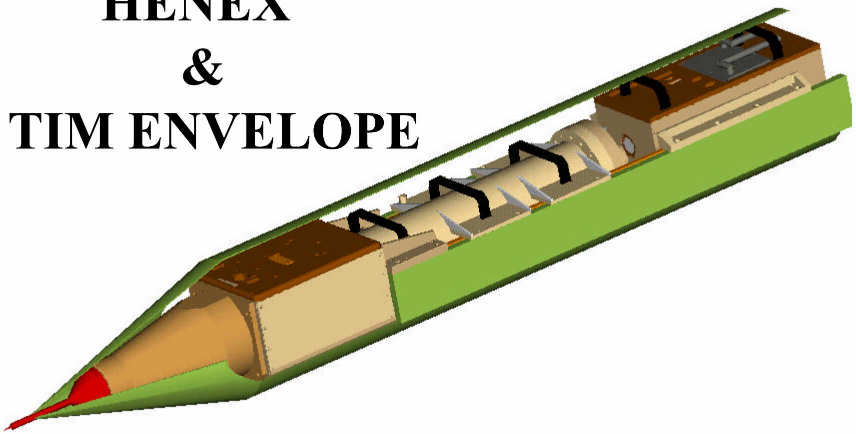
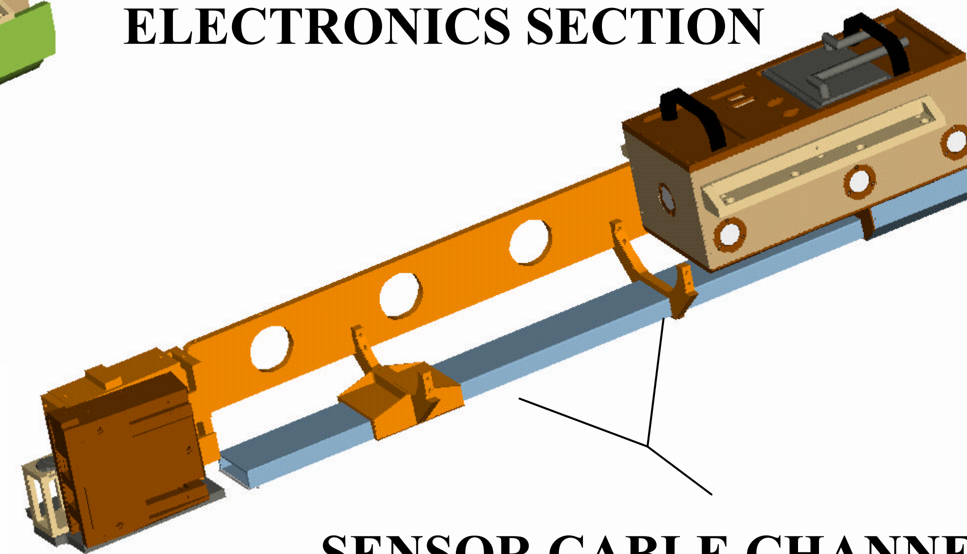
HENEX
&
TIM ENVELOPE

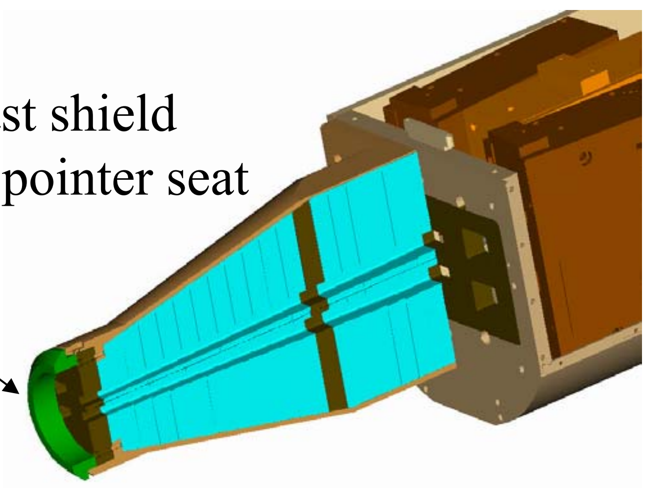


ELECTRONICS SECTION



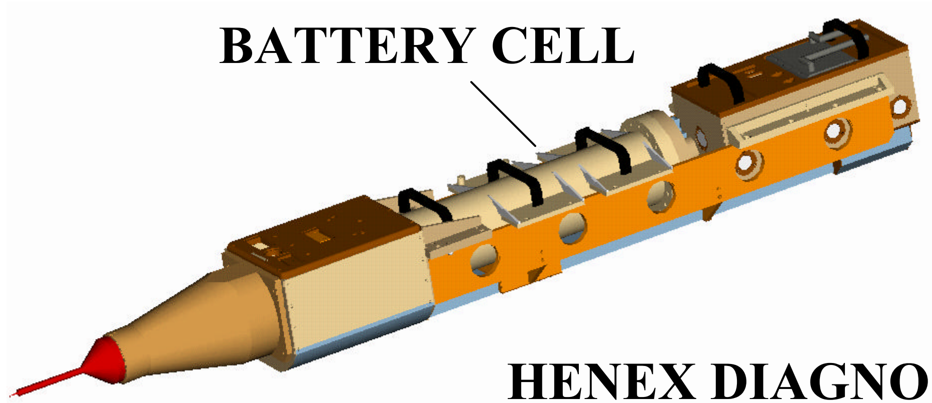
SENSOR CABLE CHANNEL

Blast shield
for pointer seat



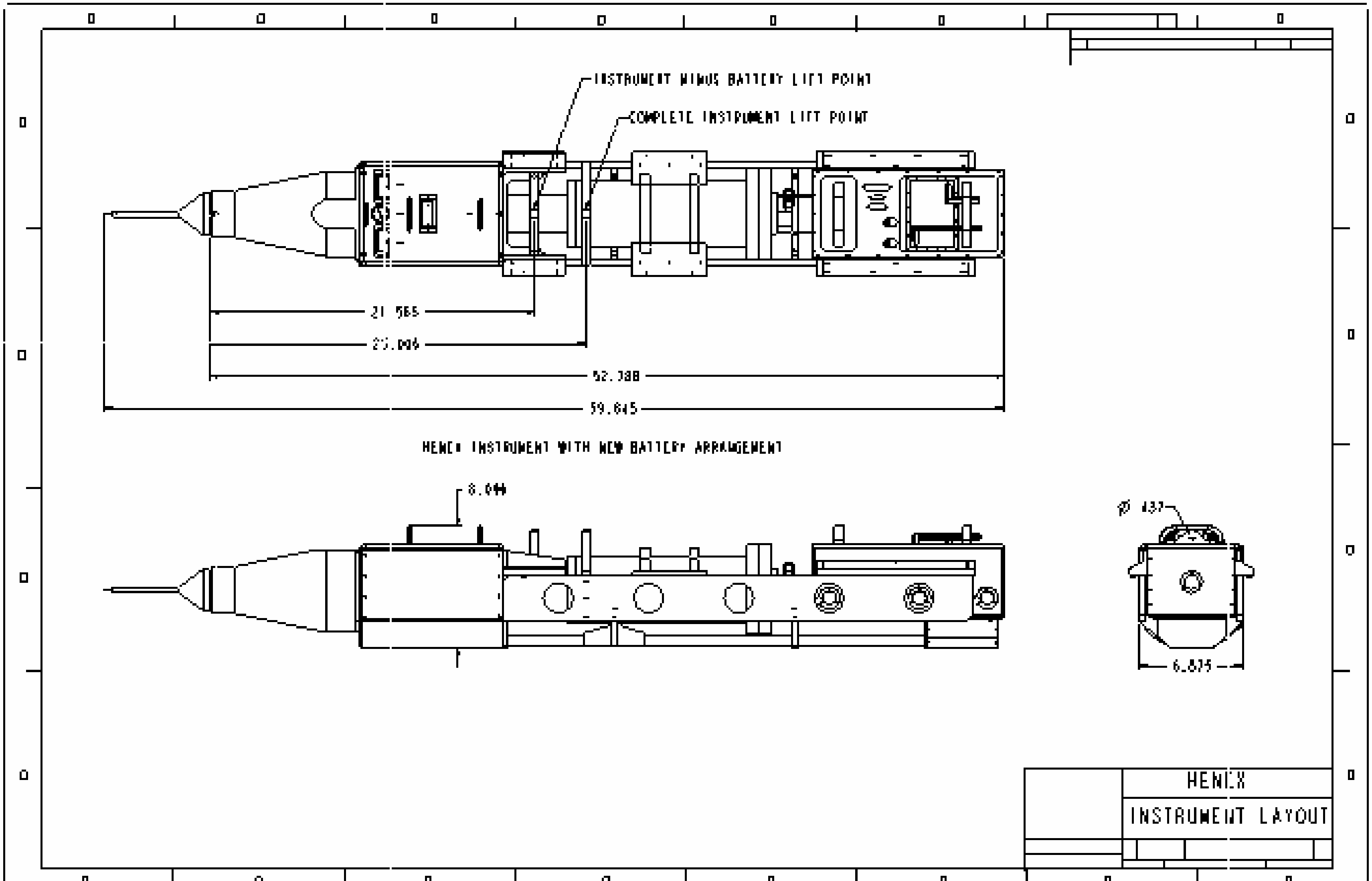
CUTAWAY OF NOSECONE
ATTACHED TO
SPECTROMETER BOX

BATTERY CELL



HENEX DIAGNOSTIC
MASS: 104.8 LBS.

HENEX Diagnostic interface drawing



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Schematic of HENEX Spectrometers

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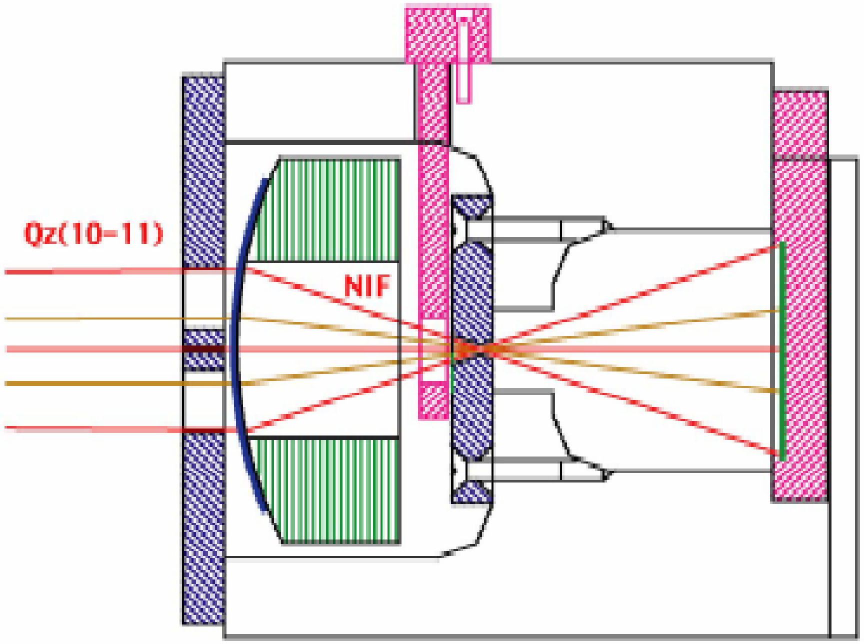
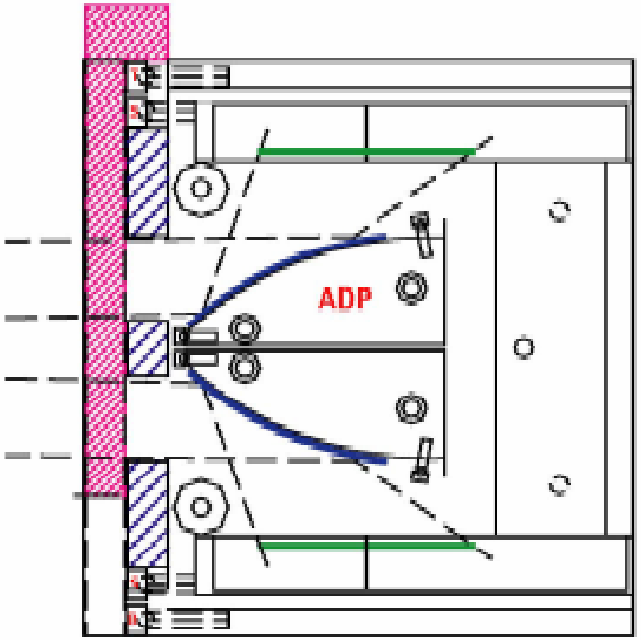
5 HENEX Channels shown in side views = plane of dispersion

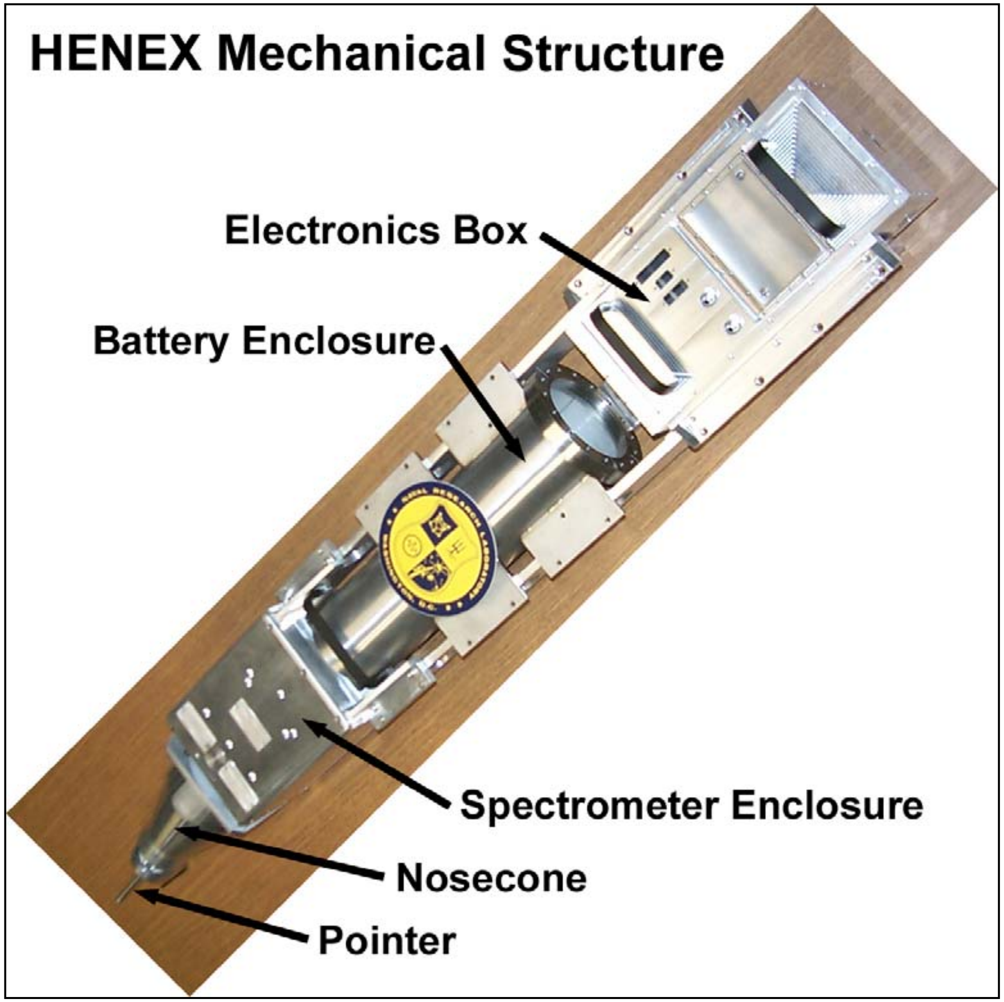


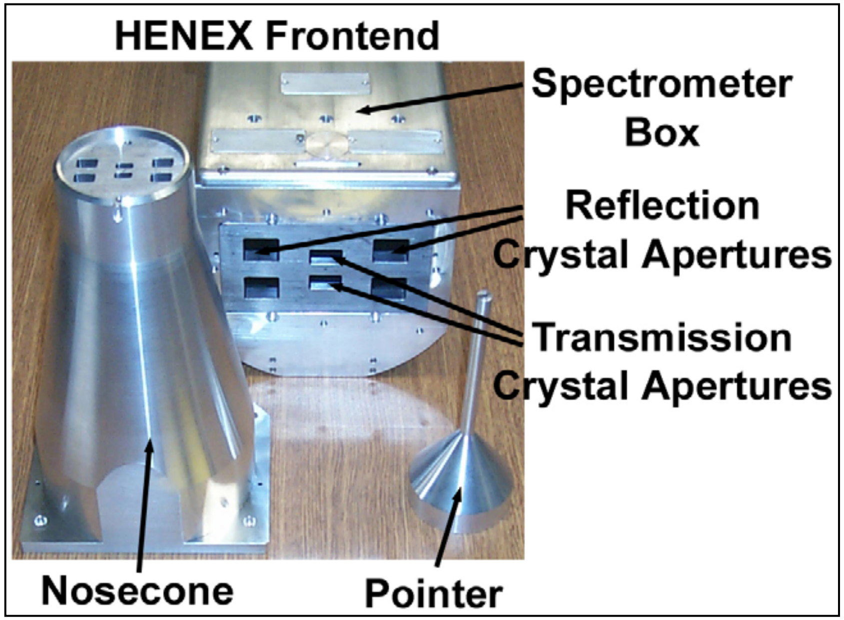
1 Transmission Channel
Radius of curvature = 4.5 inches



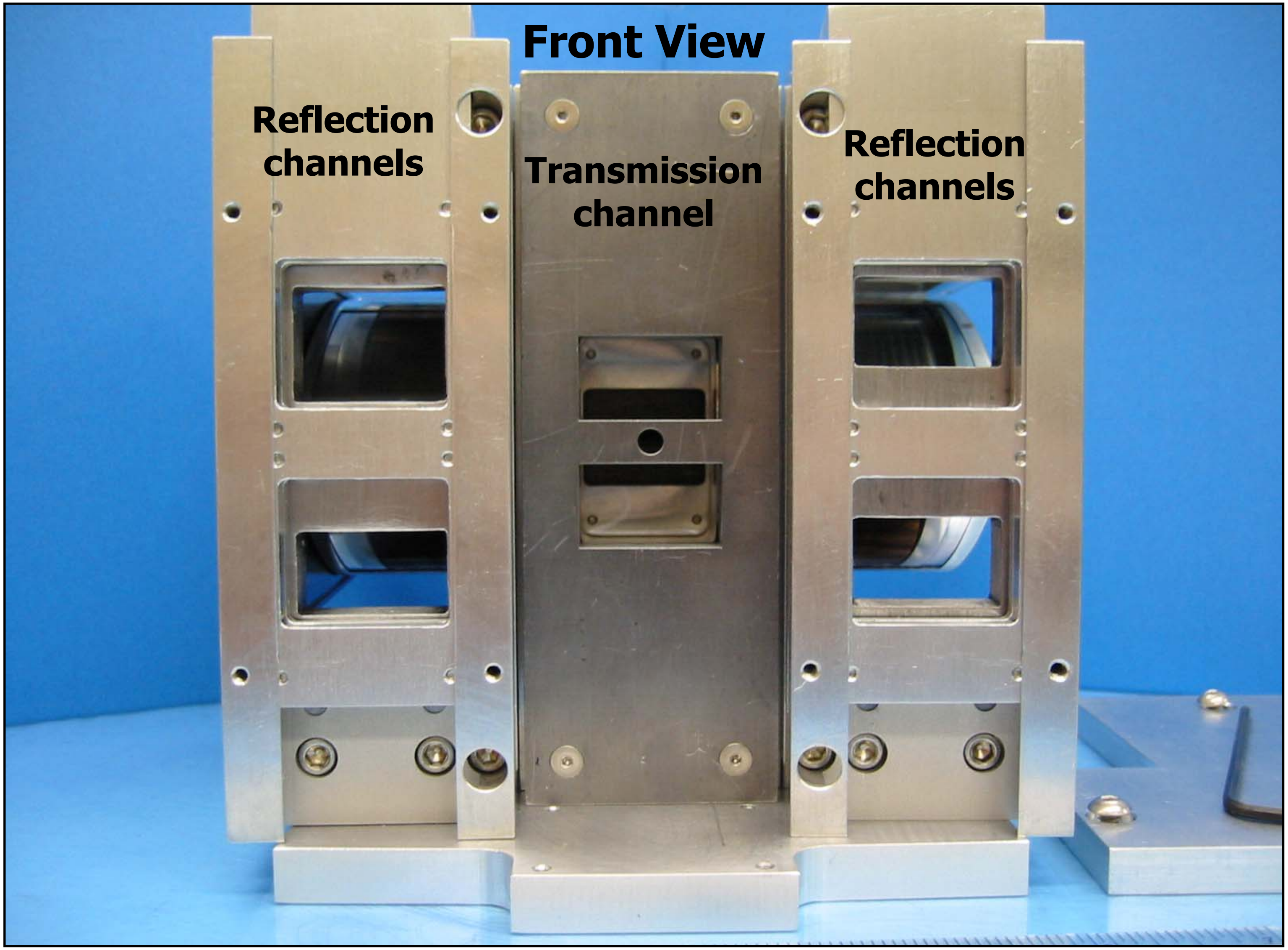
4 Reflection Channels
Radius of curvature = 5.0 inches

Status of HENEX (1)





Status of HENEX (2)



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Status of HENEX (3)

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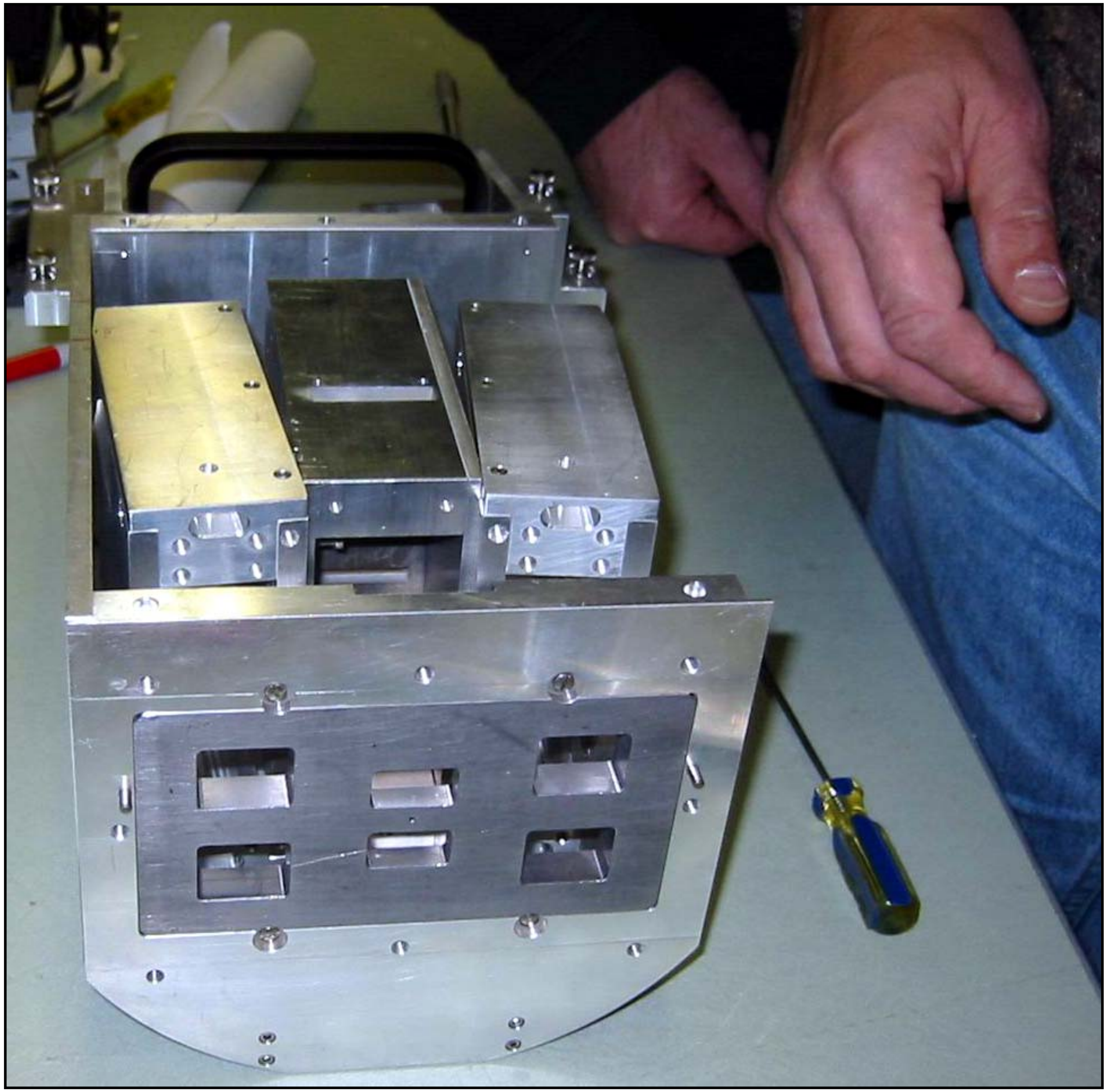

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Status of HENEX (4)

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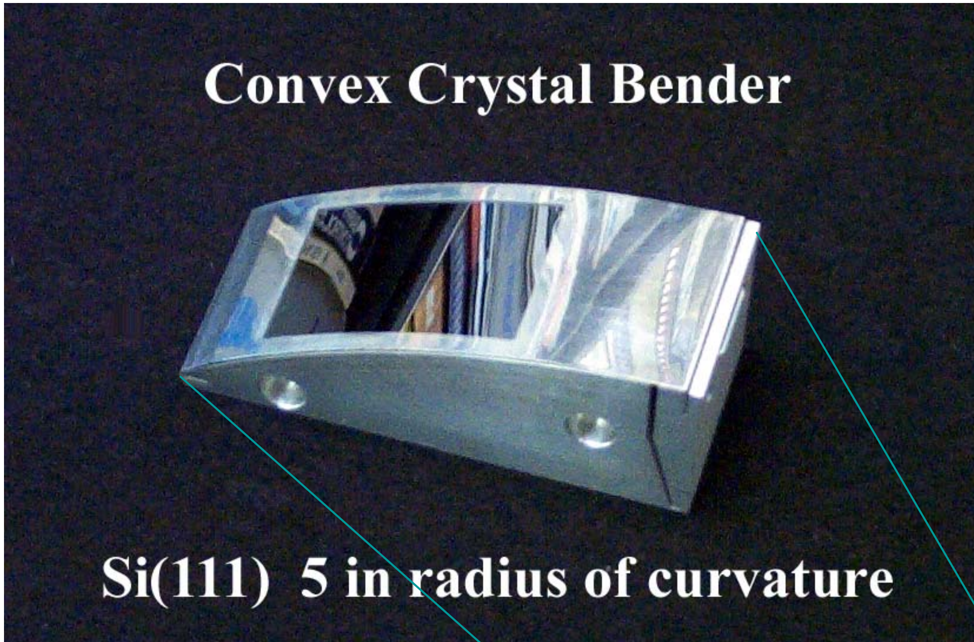

Crystals for the HENEX Channels Mounted on the Support Fixtures:

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Energy coverage of reflection crystals

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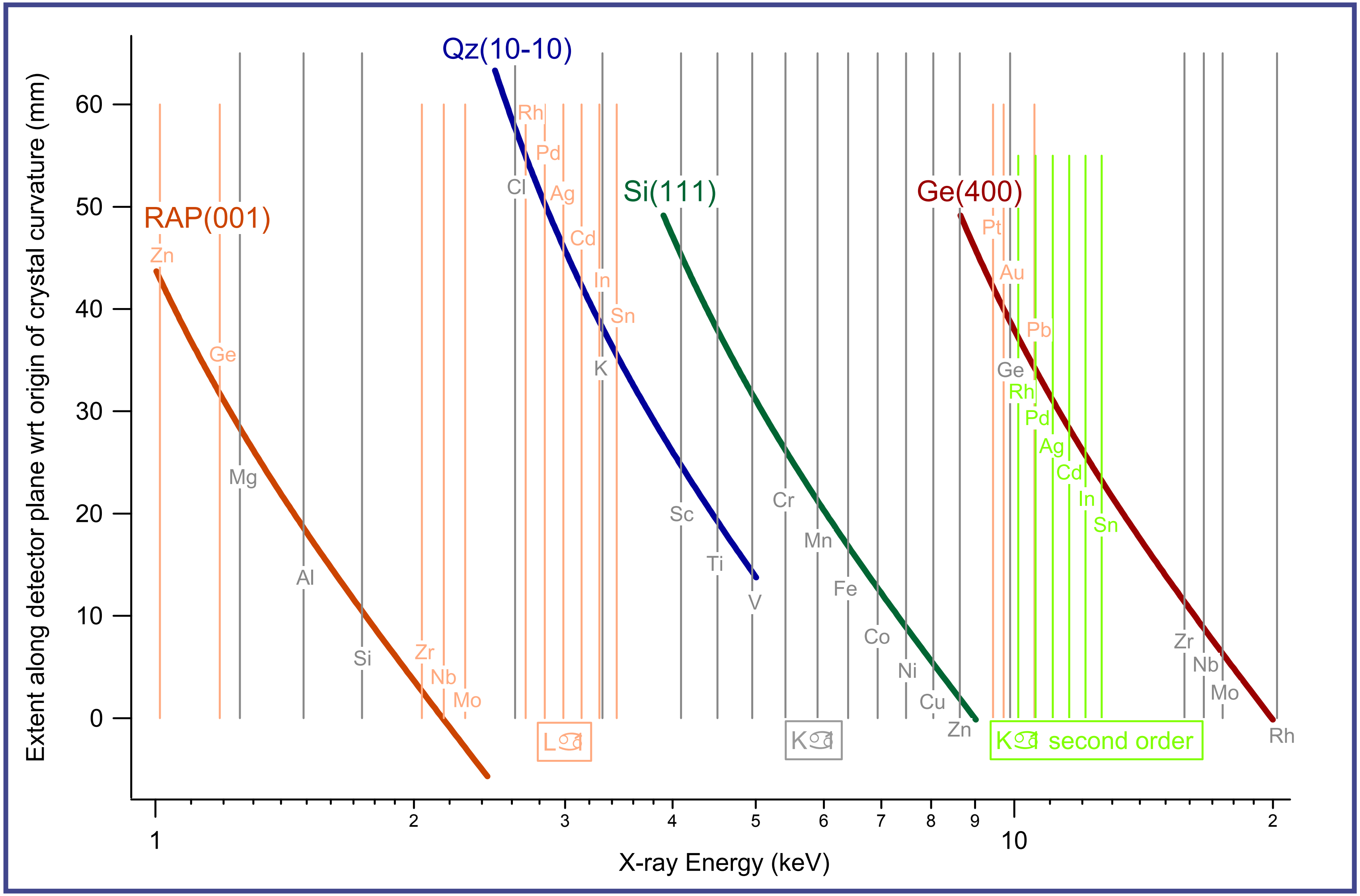
HENEX Calibration Lines



Top-level description of the HENEX diagnostic

What are its major components and features?

The High-Energy X-Ray Electronic (HENEX) Spectrometer is a five channel time integrating TIM compatible diagnostic.

What do you expect it to do?

The HENEX will record spectral data emitted from targets in the 1-20 keV range

Does it have multiple configurations?

For LLE we will use the .5 meter nose cone.

The filter packs can be changed out by hand from the top of the diagnostic while still mounted on the TIM "boat".

How do you plan to operate it?

HENEX will be deployed in an LLE TIM and use a pointer to align it to TCC

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Operational Requirements of the Diagnostic

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How sensitive is it to alignment and timing?...............NOT very, will use the T-10 timing pulse and can use alignment of +/- 250 microns to TCC.

Do you have an alignment procedure in mind?.......... YES, will use a LLE design pointer
Will it require any shot-to-shot service? …………….NO.
If so, how will we service it? …………………………..Recharge battery weekly
Does it require consumable supplies?...........................NO
Does it pose any hazards to its operators or the Omega system? ………………………………..Yes, will have beryllium filters over Sensors.
High voltages………………………………………………NO.
Sharp edges……………………………………………...NO.
Toxic chemicals……………………………………………NO.
Ionizing radiation………………………………………..NO.
Heavy and/or awkward lifting…………………………The Battery pack weighs ~40 LBS.
Do we pose any hazards to the diagnostic?.....................NO, but don't drop it.
Will it fry if we vent it with the power is on?.................NO, low DC voltage.
Can we potentially hit it with the beams or crash it into hardware?..NO, designed to fit into standard TIM envelope.

Operational Requirements of the Diagnostic cont.

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Is it TIM-based or fixed? ……………………..............TIM based
Time-integrated or time-resolved? ……………………Time - Integrated
Particle or wave-based (neutrons vs. x-rays)?............X-rays 1-20keV
What is its size / shape / weight?............................... 58” long under 100LBS
Does it require a fast trigger? ……………………..…NO
Is there a timing reference? ……………………………NO
Electrical Power? ……………………………….……NO, (Internal Battery)

Cooling water?...YES, we will interface with the Parker-Dry connections on the TIM manifold.

Wire- or fiber-based communications? ……….……Fiber, we will interface with the MPX fiber connector on the TIM Manifold. We have two ST connectors on the HENEX diagnostic.

Is the data recorded on film or electrically?.............Electrically, with five large area CMOS sensors 25 x 50mm with 48 micron pixels with a x-ray converter screen.

Fiber Optic Vacuum Feedthrough needed for HENEX on LLE

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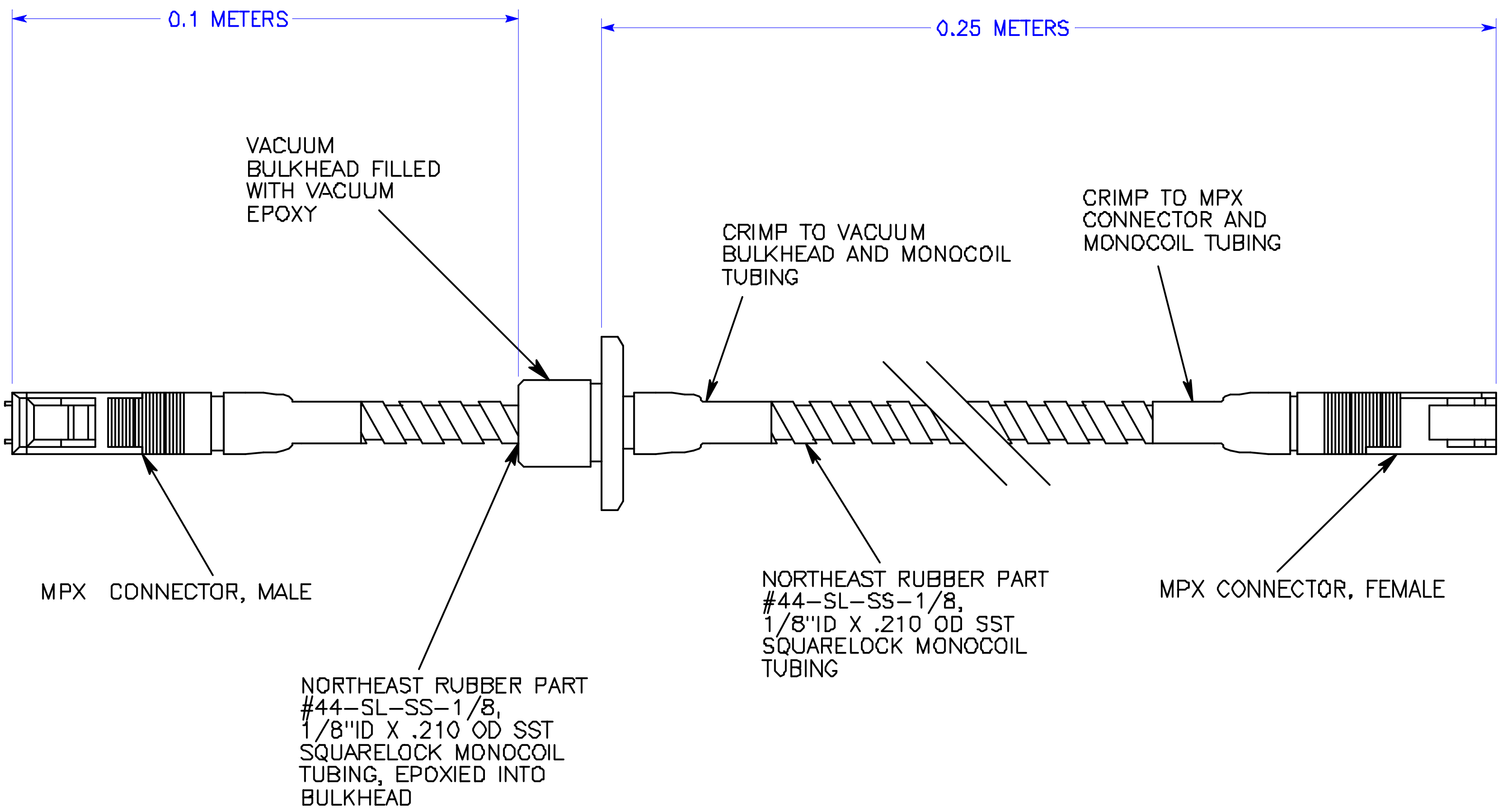

(2)

NOTE: MUST USE 62.5um RIBBON FIBER

NEXT ASSEMBLY	UNLESS OTHERWISE SPECIFIED	MATERIAL	DR M.MILLECCHIA	UNIVERSITY OF ROCHESTER LAB FOR LASER ENERGETICS ROCHESTER, NEW YORK 14623 UR LLE
	DIM. ARE IN INCHES		CM	
	DECIMAL TOL. 2PL +- .01		ORIGINATOR	
	DECIMAL TOL. 3PL +- .005	FINISH	OPT	MPX-M TO MPX-F FEEDTHROUGH, MONOCOIL JACKET 0.3M-PJx
	ANGULAR TOL. 3PL +- 1.0'		MECH	
	SURF ROUGHNESS 63		ELEC	
	EDGES .010 x 45°	DEVIATIONS FROM INTENTED SHAPE (FLATNESS, ROUNDNESS, ETC) MUST BE WITHIN STATED DIMENSIONAL TOLERANCES PER ANSI Y14.5M-1982	MANU	
	INSIDE COR RAD .010		APPROVED	
			SCALE / DATE 3/27/02	DWG No / REV A / VER

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Fiber Optic Vacuum Feedthrough needed for HENEX on LLE

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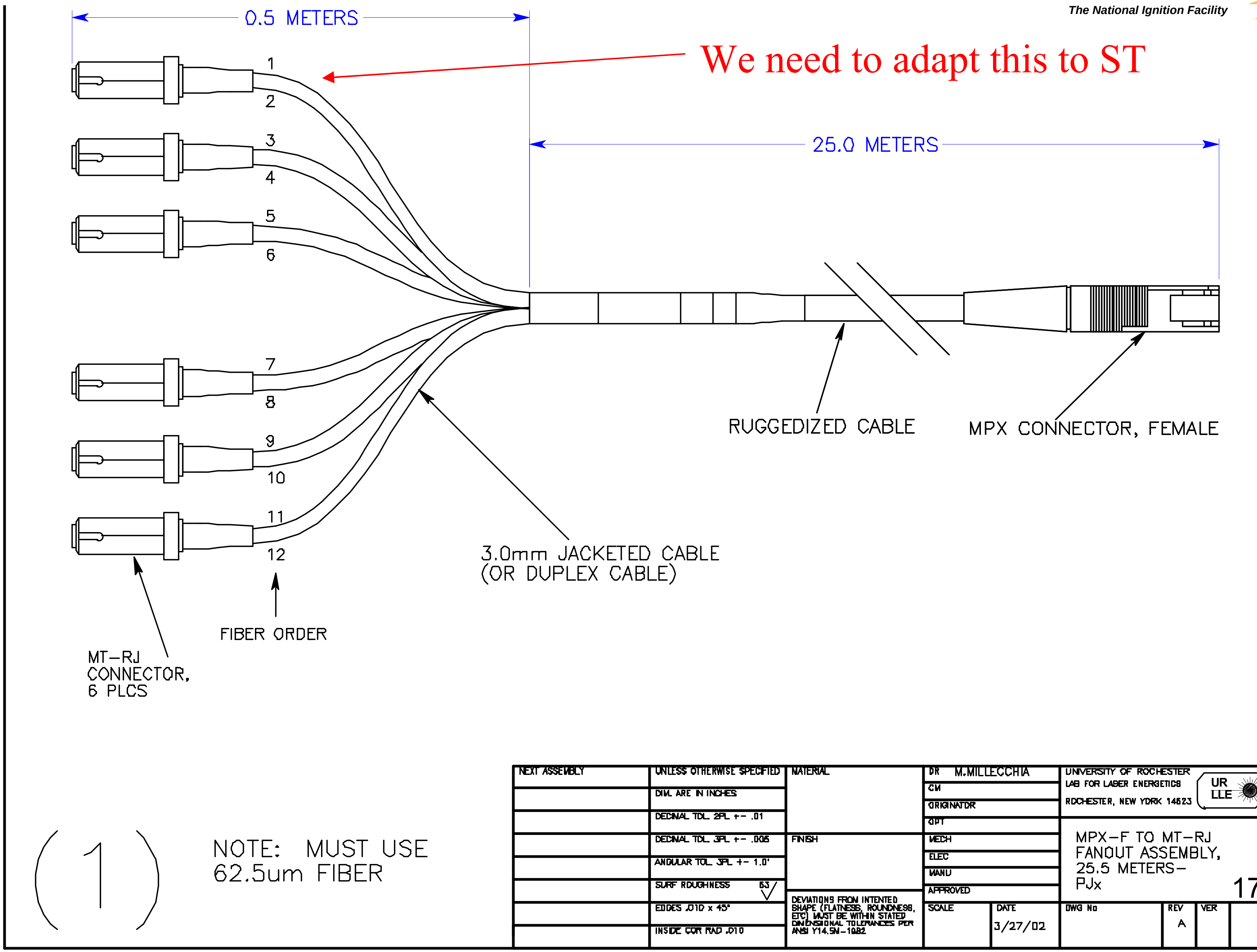

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Off-line Alignment of HENEX

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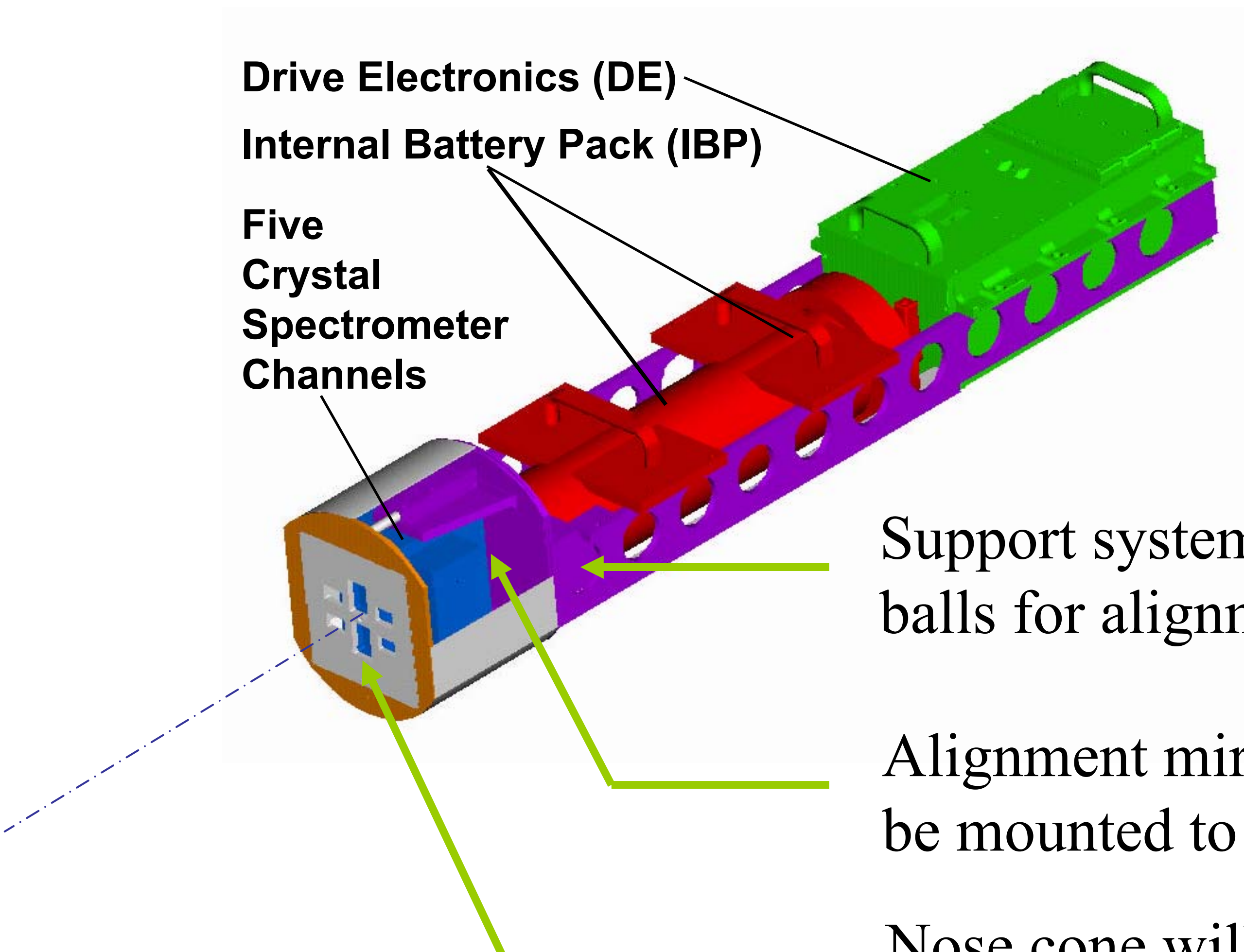


For more infromation, see the "Alignment Procedure" document on the Henex web site: http://spectroscopy.nrl.navy.mil

Support system will have tooling balls for alignment with TIM or DIM

Alignment mirror for optical axis will be mounted to the support system.

Nose cone will mount here: .5m for LLE, 2.2m for NIF

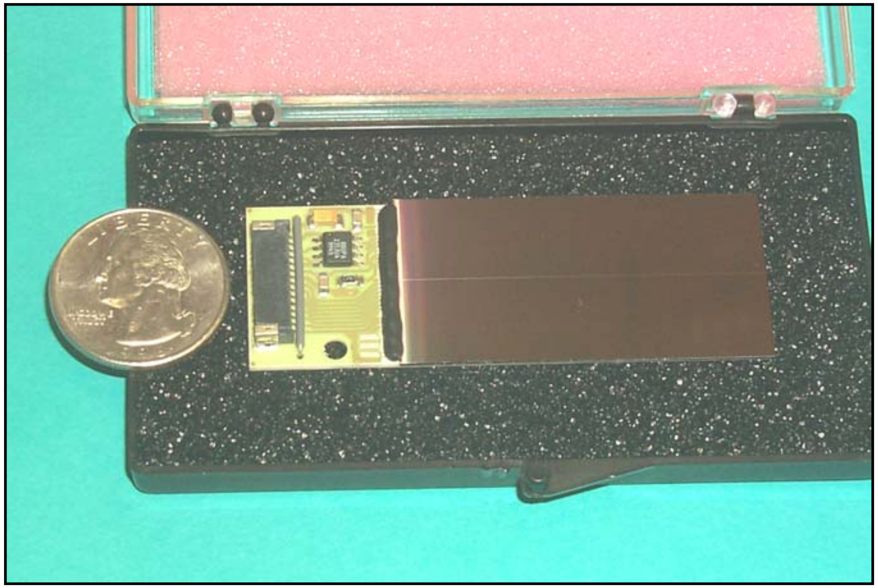
Rechargeable Battery Pack

Will weigh ~40 LBS

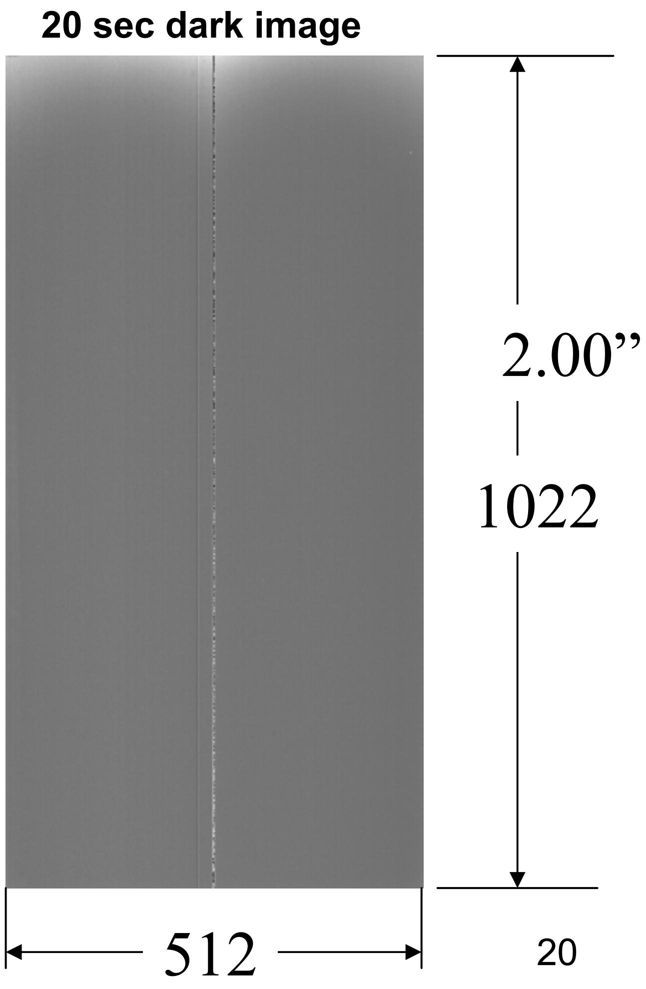
-Handles

-Captive hardware

HENEX Sensors



RadEye 1 sensor cost $2K ea.
www.rad-icon.com



Complementary Metal-Oxide Silicon (CMOS).
System on chip (SOC) design.
512 x 1022 array imager.
48 micron pixels.
24.6 x 49 mm active area.
95% fill factor, active pixels.
Rad-hard to 100K rads.
Low power, vacuum compatible.
12 bit depth pixels.

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Safety Analysis of the HENEX

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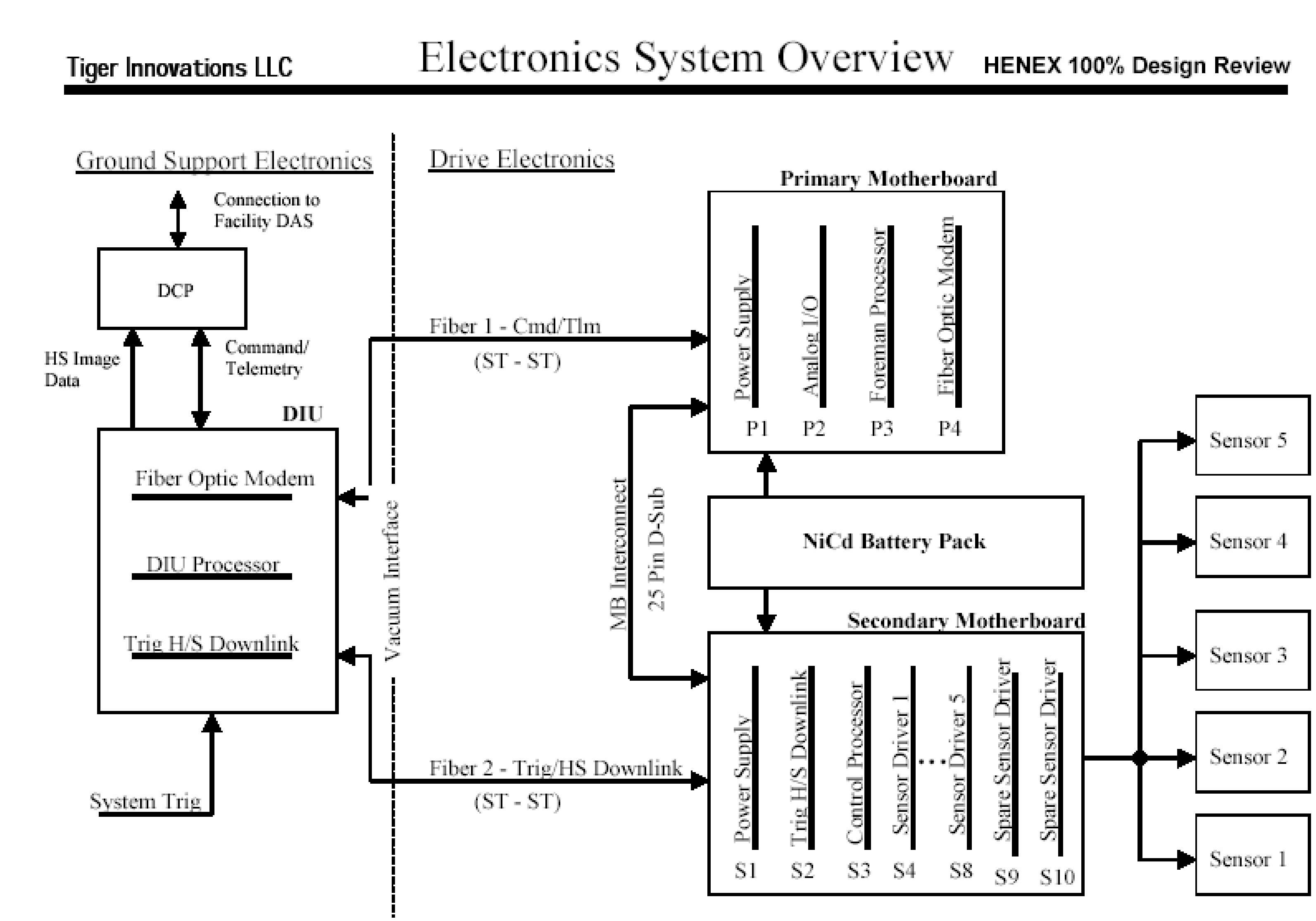
	People	Facility	Diagnostic
Battery Enclosure	-Low voltage >9VDC -100 times over rated pressure vessel -Fused output	Rechargeable unit Requires 110VAC/5amps	Required to allow operation in EMP/EMI Temperature range of -20C to +65C
Beryllium Filters	-Follow handling procedure's -Where gloves when handling it	-Follow handling procedure's -Contained with the diagnostic	Required to maintain visible light blocking and low energy light transmission as well as EMI shielding
Crystal Material	Follow handling procedures, material should not be ingested.	Follow handling procedure's All material are non-toxic	Required to obtain data
Lead Shielding	Where gloves when handling it, don't ingest All areas are covered with Aluminum	The Shielding is contained with the diagnostic	Required to protect sensors and electronics from direct exposure to X-rays.
Fiber optic cables	Not a safety concern - Use dust covers to protect fibers from particles.	Two standard 62.5 multimode with ST connectors	Required for command / control. Damage from shock or particles could reduce transmission
Drive Electronics	-Low voltage >24VDC Contained within diagnostic	No power need from DIM or TIM, only two fibers needed to command	Required for readout of the electronic detection CMOS sensors
CMOS Sensors	Coated with a converter screen coating which should not be ingested.	Contained with the diagnostic	Required to obtain data, Employ a converter screen to allow detection of x-rays.
Assembled HENEX Diagnostic	Will weigh ~ 75 LBS -Two people required to install / remove	Clean, dry storage space for offline storage. 1'x1' x 8.5'	Shock from improper handling could result in damage to crystal, sensor or electronic components.

How Henex will interface to the LLE data system



HENEX Electronics (1)

- Drive Electronics Crate
  - Motherboard-based design
    - Polarized connectors
    - Minimizes internal wiring
  - Utilizes heritage designs where possible
    - Power Supply, Analog, Foreman, F/O Modem
  - Generic sensor-slot design
    - Custom CMOS detector interface
    - Easily expandable to other custom sensor boards without hardware modification
      - Design can handle up to 15 sensor boards per crate
      - Each sensor card contains a personality id for automatic registration
      - Electronics crates can be daisy-chained if more sensor boards are required
      - HENEX crate has space for 6 sensor boards (5 HENEX sensors plus 1 spare)
- Ground Support Electronics
  - Desktop Computer based platform
    - Communicates with the Facility DAS through Front End Processor (FEP)
    - Controls Commanding/Telemetry
    - Displays and stores downloaded image data
    - Utilizes heritage DIU Processor and F/O Modem designs
    - High-speed data transfer
    - GUI for Monitoring and Control (WEB-Browser enabled)

HENEX Electronics (2)

- Heritage design
  - Heritage NiCd battery cell technology (various satellites, HXS)
  - Heritage (HXS) pressure cell design prevents any outgassing should the battery cells suffer a catastrophic failure and overheat
  - Mechanical analysis shows the pressure cell is designed with factor of 28 margin
- Instrument is designed to run entirely from the internal battery pack
  - Fiber optic connections through the chassis allow a Faraday cage around the entire instrument electronics and sensors
  - Severely reduces EMP/EMI susceptibility
  - Proven design strategy (HXS)
- At continuous full-power, battery will last ~12-16 hours
- Normal shot cycle will have the instrument at standby power for significant durations
  - 2 Hour shot cycle (Full power for 15 min per cycle) : Battery will last ~74 hours with 20% margin
  - 6 Hour shot cycle (Full power for 15 min per cycle) : Battery will last ~116 hours with 20% margin
  - * These numbers assume a 24Hour/Day operation schedule
- Alternate configurations are possible as instrument upgrades which will yield significantly longer battery lifetimes.
  - Increase battery capacity (alternate configurations, different battery cell technology)
  - Remote power down
  - Remote optical trickle charge

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HENEX Electronics (3)

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Major Control Points

- Power state
  - Standby : minimal control elements powered
  - Medium : all control elements powered, analog system at low power
  - Full : everything operating
- Time (relative to T0) of start of integration
  - Coarse control/fine control
- Time duration of sensor integration
  - Fine control
- High/Low resolution sensor readout
- Dynamic range for sensor data
  - 12bit sampling depth
- Telemetry reporting rate
- Software force trigger pulse
- Optical power gain control
  - Digital Gain Control on Fiber Optic Modem
  - Digital gain control on High Speed/Trigger Fiber Optic

Monitoring Functions

- Processor samples 24 channels at 8bit resolution
- Worst case sample rate is 0.25 Hz
- Analog telemetry is reported to the DCP with digital telemetry at approximately 0.5 Hz

Specific Drive Electronics Monitored Analog Data

- Battery Voltage
- Primary/Secondary +5V and +3.3V
- Primary +12V
- Primary/Secondary Power Supply Temperatures
  - 2 Sensors for +5V Supplies
  - 1 Sensor for +3.3V Supplies
- Primary/Secondary Battery Current
- Primary Controller Temperatures (2)
- Secondary Controller Temperatures (2)
- Fiber Optic Modem RSSI
- High Speed Data/Trigger Fiber Optic RSSI
- Six Spare Channels

HENEX Electronics (4)

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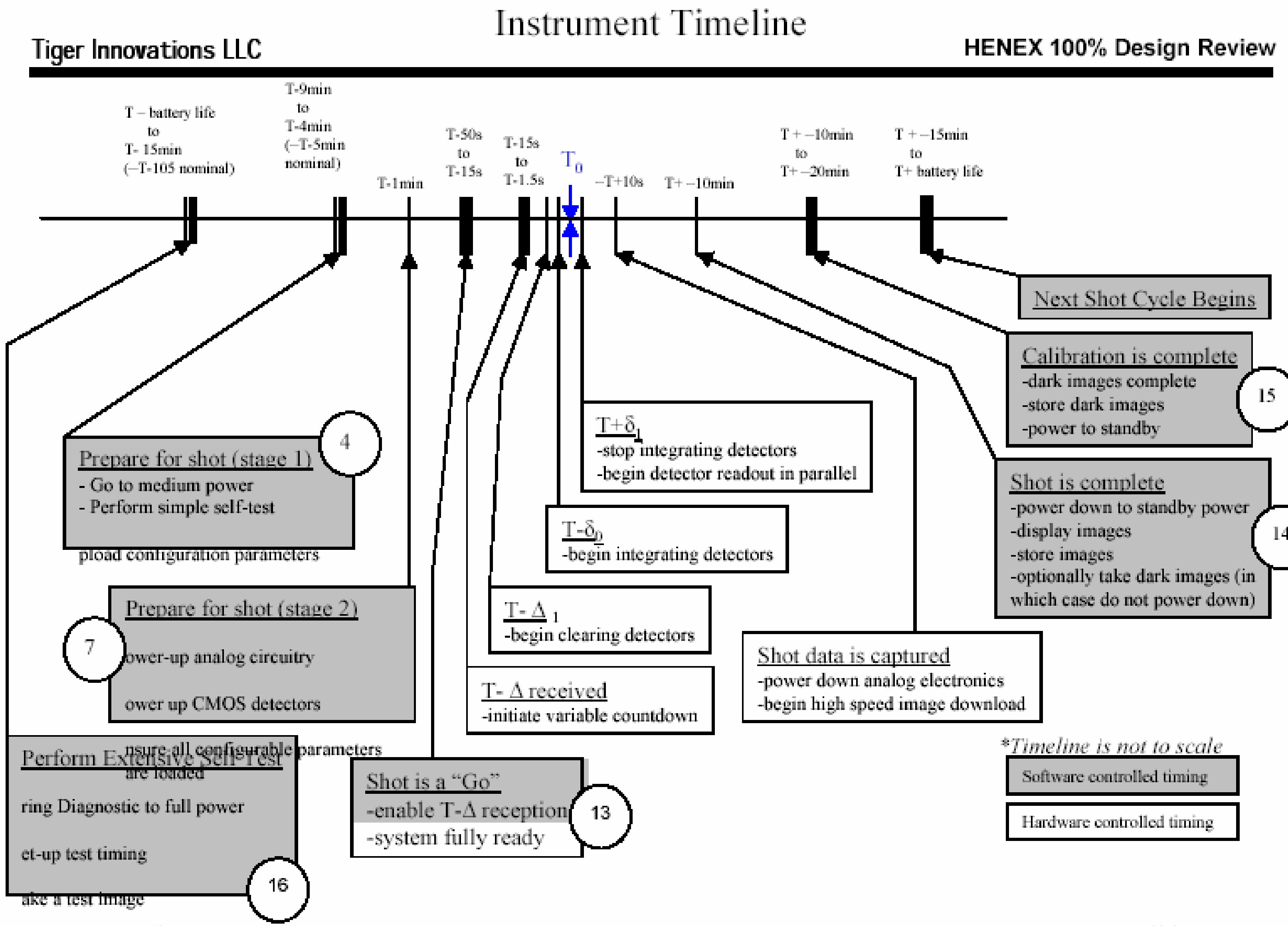

HENEX Electronics (5)

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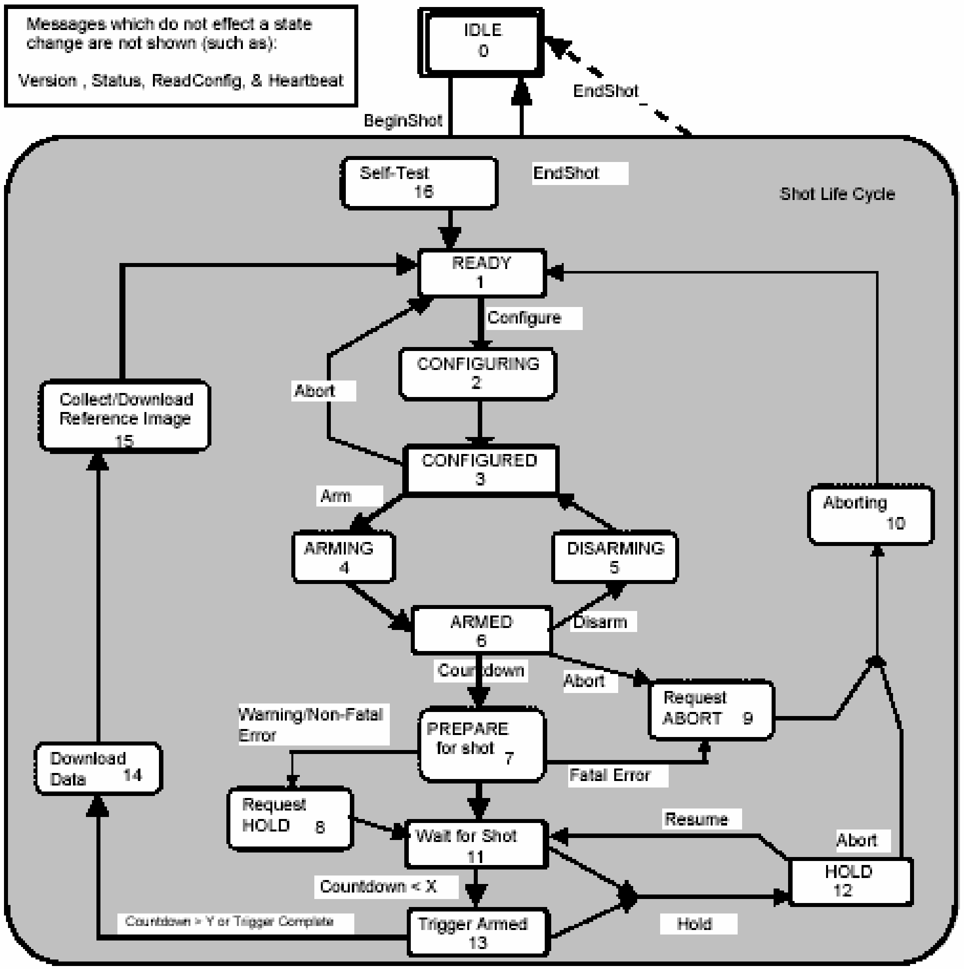
DCP State Diagram

HENEX 100% Design Review



There will exist an internal state mapping from local DCP states to the global NIF state designators (0-6). Additional local DCP state information will be provided in the user-specified area of the state descriptor.

HENEX Electronics (6)

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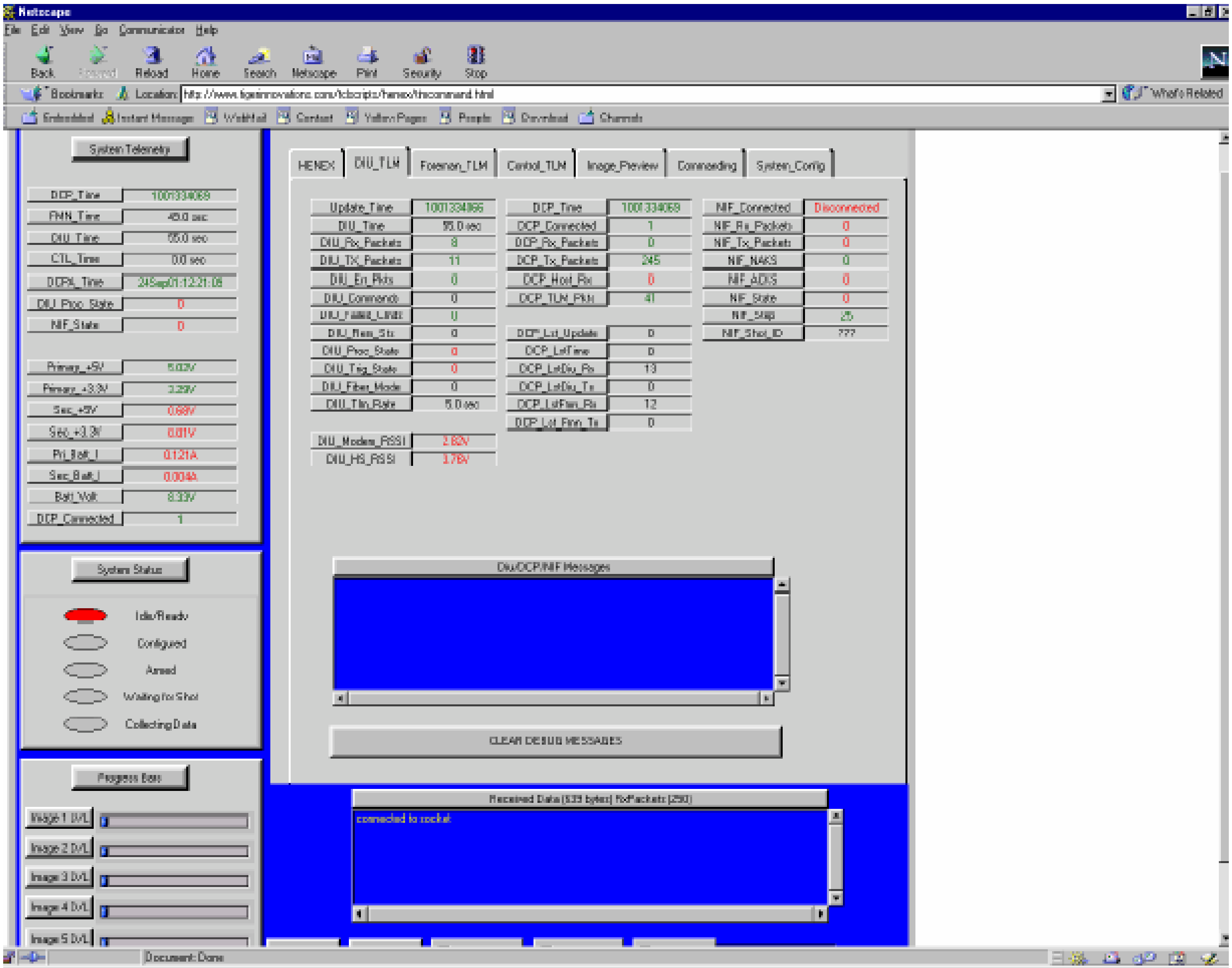
GUI – Foreman Processor Page



Contents:

- HENEX Components
- Operating Modes
- Off-Line Tests
- Deployment in the TIM
- Instrument Start-Up

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HENEX Components

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Spectrometer Hardware

Nosecone with alignment pointer

Lead and high-density polyethylene shielding

X-ray entrance aperture filters

Pin-hole open/closed and filter selection assembly on the transmission crystal channel

Transmission crystal crossover point step-wedge filter assembly

Hard x-ray shielding (Pb) for the crystals and sensors

Cylindrically bent crystal assemblies

CMOS sensor assemblies with light-tight x-ray transmission filters

Drive Electronics (DE)

CMOS sensor readout/drive boards

Foreman Control Processor board

Power management board

House keeping board

Fiber-optic data in/out board

Trigger fiber-optic board

HENEX Components cont.

The Drive Electronics (DE) Spectrometer assembly have lifting handles and interfaces to the TIM via a rail adapter system that has tooling balls which interface to the TIM *Boat*.

The cooling of the HENEX instrument is accomplished by interfacing to the LLE/NIF coolant connectors. (*Parker dry quick connect fittings)*

Internal Battery Pack (IBP) supplies power to the HENEX DE.
The IBP contains batteries housed in a hermetically-sealed enclosure mounted in the middle of the diagnostic.
The IBP hardware has captive screws and lifting handles.

In LaCave:
Diagnostic Control Processor (DCP) consists of a PC computer which is remotely located in the control room. The DCP is powered by 110 VAC and interfaces to the facility Data Acquisition System (DAS) via an Ethernet connection. The Diagnostic Interface Unit (DIU) converts the facility trigger pulse to a light pulse that is transmitted to the HENEX instrument By the trigger fiber optic cable. Interfaces with the DE and commands the sensor functions via a second fiber optic, the data fiber optic cable. All communications with the HENEX instrument are accomplished by these two fiber optics cables. The DIU is powered by 110 VAC.
Battery Recharge Interface Control Keeper (BRICK) Recharges the IBP off-line.

HENEX Operating Modes

Wake-Up Mode is activated when the power cable is connected between the IBP and the DE. A self test is carried out via the data in/out ST fiber optic cable from the DCP. The DE responds with self-test information. If the self test is satisfactory, the Standby Mode is activated.

Ready-for-Shot Mode occurs at the completion of the Ready-for-Shot handshake that is initiated by the facility.

Shot Mode is initiated by the facility trigger pulse. The trigger pulse is sent by the facility on a 50 ohm coax BNC that is connected to the DIU. The DIU command triggers a fiber Optic transmitter, which sends a light pulse via the fiber optic cable to the instrument. The HENEX instrument utilizes the existing fiber optic cables that are contained in the IIM umbilical, which we term the trigger fiber optic and the data fiber optic. The trigger activation pulse on the trigger fiber optic initiates the sensor's clearing Operation which clears the residual charge. The trigger fiber optic pulse also starts a countdown timer, inside the DE, that will trigger the sensor ~300 ms before To. The sensor's integration time will be ~600 ms. The x-ray data image is acquired by the sensor driver board.

Readout-of-Data Mode is activated after the shot. The x-ray images and dark images are downloaded via the data fiber optic to the DIU.

Standby Mode occurs after the x-ray data images and dark images have been received by the DIU and stored by the DCP. The HENEX instrument remains in the Standby Mode until commanded by the DCP.

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Off-line testing of HENEX

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The off-line testing off-line testing includes the simulation and verification of the functions carried out in the five instrument modes:
Wake-Up activation and self tests, Standby, Ready-for-Shot handshakes,
Shot (data acquisition), and Readout-of-Data (data download).

In preparation for the off-line tests, the HENEX instrument is placed near the DCP and the DIU. Connect the two ST fiber optic cables in the following manner:
(1) The data in/out ST fiber optic connects to the DCP.
(2) The trigger ST fiber optic connects to the DIU.
Connect the cable to the Internal Battery Pack (IBP).
This action initiates the instrument's Standby Mode.

The DCP is connected to the facility DAS via an Ethernet cable. The DAS conducts a normal shot sequence with the HENEX instrument riding along off-line. The handshake commands are tested, and the facility trigger pulse is routed to the off-line testing area. The HENEX instrument records an integrated (dark) exposure on the sensor with the normal integration time. Based on experience with the sensor, the dark image has a background level that is easily recognized and serves to verify the data transfer function.

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Deployment of HENEX in TIM

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The following instrument components are carried to the (TIM or DIM) for deployment:
Internal Battery Pack (IBP) in its hermetically-sealed enclosure.
Assembled spectrometer/nosecone, Drive Electronics (DE) and the pointer assembly.
The HENEX components are assembled into the (TIM or DIM) in the following order:
The assembled spectrometer and DE attaches to the TIM "BOAT" with spring-loaded captive 10-32 PEM hardware.
The IBP has lifting handles and is installed on the center of the HENEX in the TIM or DIM. The IBP has spring-loaded captive 10-32 PEM hardware to interface with the existing mounting holes on the TIM "boat".
The two vacuum-side ST fiber optics, Jack cable assembles approximately 36" long, are routed to the ST fiber optic connectors that are located on the top side of the DE. The facility MPX fiber connector is used for the HENEX data and trigger fiber optic (routed through the opening in the handles of the DE).
Insert the mating Parker dry connectors from the DE structure to complete the connection of the cooling loop (routed through the opening in the handles of the DE).
Connect the cable from the DE to the IBP. This action initiates the HENEX instrument's Standby Mode.
Connect the atmosphere-side ST fiber optic Jack cables to the remotely located DIU.

Instrument Start-Up

In the remote location of the DIU and the DCP:
Power-up the DCP, which initiates the HENEX instrument's Wake-Up Mode.
The instrument's self test is performed.

Connect the DCP to the facility Ethernet.
Conduct the DAS system test of the HENEX instrument. Conduct the sensor aliveness test as discussed above Off-Line Tests section. Proceed if the test image is acquired.
At the TIM location:
Verify that all cables are safely routed inside the TIM space envelope and that the D-sub connector RF cover is installed.

Install the HENEX instrument's pointer and proceed with the normal diagnostic instrument pointing operation. Save the deployed position values, retract the instrument, remove the pointer, and stow the pointer. Pump down the TIM and deploy the HENEX instrument to the previously saved position in preparation for the laser shot.

Major Component Suppliers/Costs

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Item	Description	Part Number	Cost	Vendor, address, phone
Neutron Shielding	Ultra High Density Polyethylene	Sheet PN. UHMWNAT 2.0" 12"x12"	$40.00	Read Plastics 12331 Wilkins Avenue Rockville, MD 20852 Phone 301-881-7900
X-ray Shielding	Hard LEAD alloy [Calcium and Tin .07% and 1.5%]	Hard LEAD alloy Sheet .250", .375", .500" thickness.	Call for quote ~$.312 per pound.	SMC Seafab Metals Company,1112 N. V.I.P. Blvd. Casa Grande, AZ 85222, Phone (800) 426-7082
X-ray Shielding	Tantalum sheet	.010" thick 24"wide ~85" long	453.25 per LB	Strategic Aerospace Materials 150 Park Avenue Hicksville, NY 11801 Phone 516-932-3322
X-ray Shielding	Lead sheet	.016" thick 48" x 25'	475.00 Lot	Strategic Aerospace Materials 150 Park Avenue Hicksville, NY 11801 Phone 516-932-3322
Beryllium Filters	99% pure foil	PF-60	792.00 ea	Brushwellman
CMOS Area Sensors From Rad-icon	1022 x 512, 48 micron pixel size	RadEye 1	2000.00 ea	Rad-icon Imaging Corp 3193 Belick Street, Unit 1 Santa Clara, CA 95054-2404 Phone 408-486-0886
Quartz Crystal	Transmission channel 11.4 – 28 keV	225mm thick x	1k ea	Sawyer Crystal Systems 1601 Airport Rd.Conroe, TX 77301
RAP 001 & ADP 101 Organic Crystals	Reflection channels RAP .9k- 2.1 keV ADP 2.0 –4.1keV	.250 mm thick x	1 –2 k ea	Saint-Gobain Cristaux BP 521 77994 Nemours CEDEX Phone (33) 164 45 10 10 Fax (33) 164 45 10 02 www.saint-gobain.com
Germanium Crystal (400)	10-20kev reflection channel, fused silica could be used as a substitute	.16 mm thick x	1k ea	Eagle-Picher Technologies, LLC PO Box 47, Joplin, Missouri 64802-0047 USA or C & Porter Streets, Joplin, Missouri 64801 USA Phone: (417)623-8000 Fax: (417)781-1910
Silicon Crystal (111)	Reflection channel 3.9 –9keV	.200 mm thick x	1k ea	Virginia Semiconductor, 1501 Powhatan Street Fredericksburg, VA 22401-4647 USA Phone: (540) 373-2900 Fax: (540) 371-0371 www.virginiasemi.com
Polishing of Quartz Crystal	For transmission channel	.225mm thick		Bond Optics, Inc. Etna Road, Box 422 Lebanon, NH 03766
Sinllilator / Phosphor converter	1-2 keV, 3-8keV,9-20 keV	Gadox screen	~600.00ea	Applied Scintillation Technologies 12 President Point Drive Annapolis, MD 21403 410-263-6005
K-Line filters	Pure Metal foils			Alfa
Sintered Breathers	Stainless Steel	Need for electronics box / EMP, EMI	500 min order (get Samples!)	Mott Corporation 84 Spring Lane, Famington, CT 06032 Phone 860-747-6333 Fax 860-747-8629
Cabling for sensors	15 pin connectors	Twisted pair shielded,		Custom made by NRL, interfacing with Samtec connectors jumpers (FJ-15-D-06.00-4)
Connectors for sensors	inside drive electronics on Sensor board		3.00 ea	Samtec USA P.O. Box 1147 New Albany, IN 47151-1147 Phone: 800-726-8329 Fax 812-948-5047
Connectors for sensors boards in drive electronics	Interface to Mother Board	On Mother Board = 84699-650 On Sensor Board = 87402-150	~$5.00ea Min Qty (100)	FCI 5511 Capital Center Drive Suite P-120 Raleigh, NC 27606 phone 919-859-7200 Fax 919-859 7201 www.fciconnect.com
Fiber Optic connectors	SMA /ST bulkhead connectors	These are treaded into the top plate of the drive electronics at a 45º angle		Newark
Fiber Optic cable	SMA-ST cable / Tefzel jacket			Fiber Guide
Epoxy for potting cable connectors and other things		EPO-TEK 301	25.00 for A&B kit of small size	Epoxy Technology 14 Fortune Drive Billerica, MA 01821 Phone: 978-667-3805 Fax :978-663-9782
Vacuum Electrical Feed-though	HD D-sub 44 pin connector on 2-3/4CF	Needed for Battery enclosure that will power diagnostic during shot	800.00 ea	Douglas Engineering Company 14 Beach Street Rockaway, NJ 07866 Phone 973-627-8230 Fax 973-627-5798
Rechargeable NiCad batteries	4.4 A/hours at 1.2VDC Tabbed "D" cells	PN.P158T-ND	6.7245 ea /100	Digi-key 701 Brooks Ave. South Thief River Falls, MN 56701-0677 Phone (1-800) 344-4539 www.digikey.com
Drive & Support Electronics	EMP/EMI proof Fiber Optic Control	DCP, DIU, DE		Tiger Innovation (TI) 3610 Vacation Lane Arlington, VA 22207Sales@tigerinnovations.com Website: www.tigerinnovations.com Phone:703-248-8394 POC: Rob Atkin
Shipping cases	49.75" x 20" x 13.75" id PN. 1SKB-H5020W	Nose cone, Diagnostic	189.00	CPD Industries14020 Central Ave. Unit #530 Chino, CA 91710 USA Phone (800) 882-4730 Fax (909)- 465-5598Website: www.casefoam.com